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SPECIFICATIONS FOR MATERIALS RECOVERED FROM MUNICIPAL REFUSE

H. Alter, et al

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By

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Washington, D.C. 20036

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment --air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

This report presents a summary of research directed toward development of specifications for defining the qualities of materials separated and recovered from municipal solid waste for subsequent sale and use. Specifications presented represent first efforts towards providing potential users of recovered materials with a basis for quality assurance.

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National Environmental
Research Center, Cincinnati

ABSTRACT

Specifications presented in this report represent first efforts to define uniform qualities of materials separated from municipal solid waste in resource recovery processing plants for subsequent sale and use. The establishment of specifications adds value to outputs and promotes acceptance by users as a result of providing a basis for quality assurance. Recoverable materials investigated in this study are:

- Folded newsprint and corrugated paper
- Ferrous metals
- Aluminum
- Other nonferrous metals
- Glass cullet
- Inorganic fines
- Mixed organics (for fuel)

Indications of possible contamination were obtained on a limited scale by reviewing literature, visiting plants, and coordinating with the activities of a companion research grant which included processing pilot quantities of municipal solid waste from several cities. The resulting target specifications were written as goals for plant design; the targets seem achievable with existing technology. The likelihood of these target specifications being accepted was checked by reviewing them with officials of appropriate companies and trade associations.

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PROLOGUE

Faults in Specifications*

The special fault which characterizes many specifications is the attempt on the part of the one who draws the specification to make it a place to show how much he knows. We have seen specifications which were apparently drawn with no other thought in mind than to embody all the knowledge the writer had on the subject. No discussion is needed on this point. The folly of it is apparent to all.

Another fault is putting too many restrictions into the specification. According to our views, the fewer possible restrictions that a specification can contain, and at the same time afford the necessary protection in regard to the quality of the materials, the better the specification is. In some of our specifications we have only one test; in others, perhaps half a dozen; the effort, however, being always to have the minimum number which will yield the product that is required.

A third fault in specifications is in making the limits too severe. Some writers who draw specifications apparently put themselves in a position of absolute antagonism to those

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*The Life and Work of Charles Benjamin Dudley, STP 1, American Society for Testing and Materials, Memorial Volume, pp. 127 to 128. Mr. Dudley was President of ASTM, 1902-1909.

who are to make the material, and seem to have as a permanent thought in their minds to tie them down to the extreme limit. The maximum that a single test piece shows, the minimum of an objectionable constituent that may be obtained by analysis, the extreme point in elongation that by chance some good and exceptional sample gives, are made to represent the total output of the works. It is, perhaps, needless to say that such extreme figures are the worst possible mistake in making specifications.

SECTION I

CONCLUSIONS

Tentative or target specifications for materials offered for sale by resource recovery plants must be agreed to between processor and buyers in advance of start-up of such plants. The targets result from technology likely to be employed and the needs and requirements of user industries, i.e., the buyers of the recovered products. Separated materials are likely to be accepted for purchase by users only if the recovery processes are chosen and operated to meet the specification for reuse along with regular feed-stocks into existing processes.

The specifications for many of the recovered materials must contain considerable detail, even limits of chemical composition. This is a more exacting requirement than practiced currently in the commerce of secondary materials. The more exacting requirements are detailed to assure buyer and seller alike that the recovered materials did not become contaminated by contact with mixed, municipal solid waste or by the mechanical and chemical processing required to separate the materials from this waste. Unfortunately, it is not always possible to provide this detail and, in many instances, the specification is a qualitative description only.

The target specifications are recommended subject to the consensus, and adoption by potential producers, users and

cognizant professional and trade associations. Before such adoption the target specifications presented here may serve as a starting point for negotiations for the sale of recovered fractions from resource recovery plants.

Additional activities are required to further refine and finally to have adopted specifications for materials (and fuel or energy) recovered from municipal solid waste. The activities associated with preparation of this report included assistance in the formation of Committee E-38 of the American Society for Testing and Materials (ASTM). It is expected that this committee will continue to work toward establishment of final specifications in the field.

SECTION II

RECOMMENDATIONS

This report contains recommended target specifications for materials apt to be recovered from mixed, municipal solid waste. They were developed by consideration of user technology and needs, and through negotiation with user industries. As such, they should be considered the first step toward acceptable specifications for negotiating the sale of recovered fractions from any proposed resource recovery plant. Final adoption must await full consideration by the users and producers of the recovered materials and by cognizant professional and trade associations.

Wherever possible, the specifications were tested against analyses of fractions from municipal solid waste. The fractions were separated and selected so as to represent, as nearly as possible, the state of the art of separation processes. Because at the present time there are few full-scale resource recovery plants in operation, it was not possible to test the specifications further. As such, it is recommended that they be considered subject to further test and analysis as plants are built and put on-stream.

It is recommended that refinements of specifications for recovered materials be coordinated with cognizant standards setting organizations such as ASTM, NARI, ISIS and ANSI.

SECTION III

INTRODUCTION

A specification for a material is the designation of particulars of form and/or composition as the basis for acceptance or rejection, for sale or use. The specifications for a raw or processed material may also be used to determine price. Material specifications are a normal part of commerce and an important tool for technological processing industries.

Specifications are equally useful in the commerce of both virgin and secondary products. Organizations such as the National Association of Recycling Industries (1) and their commodity division, the Paper Stock Institute (2), have established material descriptions, specifications, and grades of secondary materials (3). These also form the bases for commodity quotations in the scrap market (4).

There is great, recent interest in implementing resource recovery from municipal waste. Various processes have been proposed to recover, for resale and reuse, a variety of metals, glass, and paper (5). It was the objective of the work reported here to establish specifications for the materials apt to be recovered from such processes to facilitate their purchase by user industries. Several general criteria or guidelines were used in formulating the specifications:

(a) Recovered materials should be processed to be sold in form and cleanliness that will require minimum perturbation to user industries (6).

(b) The specification should permit forms easily produced, shipped and handled.

(c) The specification should be capable of being tested using existing (and hopefully simple) analytical techniques.

(d) The specification should be within the state of the art of known recovery systems and processes.

(e) The specification should be as quantitative as possible, avoiding non-specific terms, such as "clean".

(f) The specifications developed are targets, or "first generation", subject to revision with experience, with future involvement of interested parties, and by voluntary consensus. (These are normal steps in the evolution of any specifications).

In developing specifications, no constraints were imposed as to the processing technology to be employed. It was considered that any of the recovery systems described to date (5) might be employed to meet specifications, by themselves or with the addition of some few simple processing steps.

The materials considered were newsprint, old corrugated boxes, steel, glass, aluminum, other non-ferrous metals, inorganic fines and a mixture of organic materials suitable as supplemental fuel for direct firing with coal or oil to raise steam.

The only paper products considered to be recoverable were portions of the old corrugated boxes and some newspaper. It is believed that if newspaper is prebundled by the householders, it can be picked from the refuse prior to

mechanical processing (7). The remainder of the paper, that mixed with food and garden waste, and portions of composite packaging, are unlikely inputs for modern, high-speed paper-making processes. Some of the reasons for this are discussed in the sections following dealing with paper specifications.

One of the outputs of any materials recovery process using mixed, municipal refuse as the feed stock is a complex mixture of organic materials consisting of the mixed papers, food wastes, garden wastes, plastics, etc. Possible alternative uses for this mixture include compost, feedstock for pyrolysis, and as a refuse-derived fuel or RDF. No specifications for compost were considered because it is unlikely this process will gain widespread acceptance in the United States (8). Similarly, no specifications were considered for feedstock for pyrolysis; the methods described to date seem designed to accept a wide variety of feedstocks, more like a disposal unit (9). A possible specification for refuse-derived fuel for direct firing (10) was considered and is included.

Not everything in municipal waste has a value or high enough value to make recovery worthwhile. Therefore, there will always be a fraction for disposal (11). No specifications for waste products or for disposal practices were considered.

The specifications described here are designed to serve as bases for acceptance testing of the recovered materials. As

such, they should be independent of the resource recovery technology employed to separate them. However, as an example of technology which might be used, Figure 1 shows a series of steps which could constitute a material recovery process. Waste products and recovered products are indicated.

Statement of the target specifications does not guarantee buyers will accept the specification. In other words, recovery to specification does not guarantee saleability. The general considerations of the background and structure of the markets for the recovered materials are covered adequately elsewhere (12).

As a broad generalization and simplification, specifications for materials may be categorized as describing performance, origin, or composition. Performance specifications are used when the material must meet mechanical or chemical criteria, such as strength, durability, weathering, etc. This type of specification is more suited to finished products; e.g., to iron pipe or steel girders than to the base material, such as iron or steel. Hence, performance specifications are not applicable to products recovered from municipal refuse.

Origin specifications have been used to advantage by the secondary materials industry for longer than the sixty years since the founding of what is now called the National

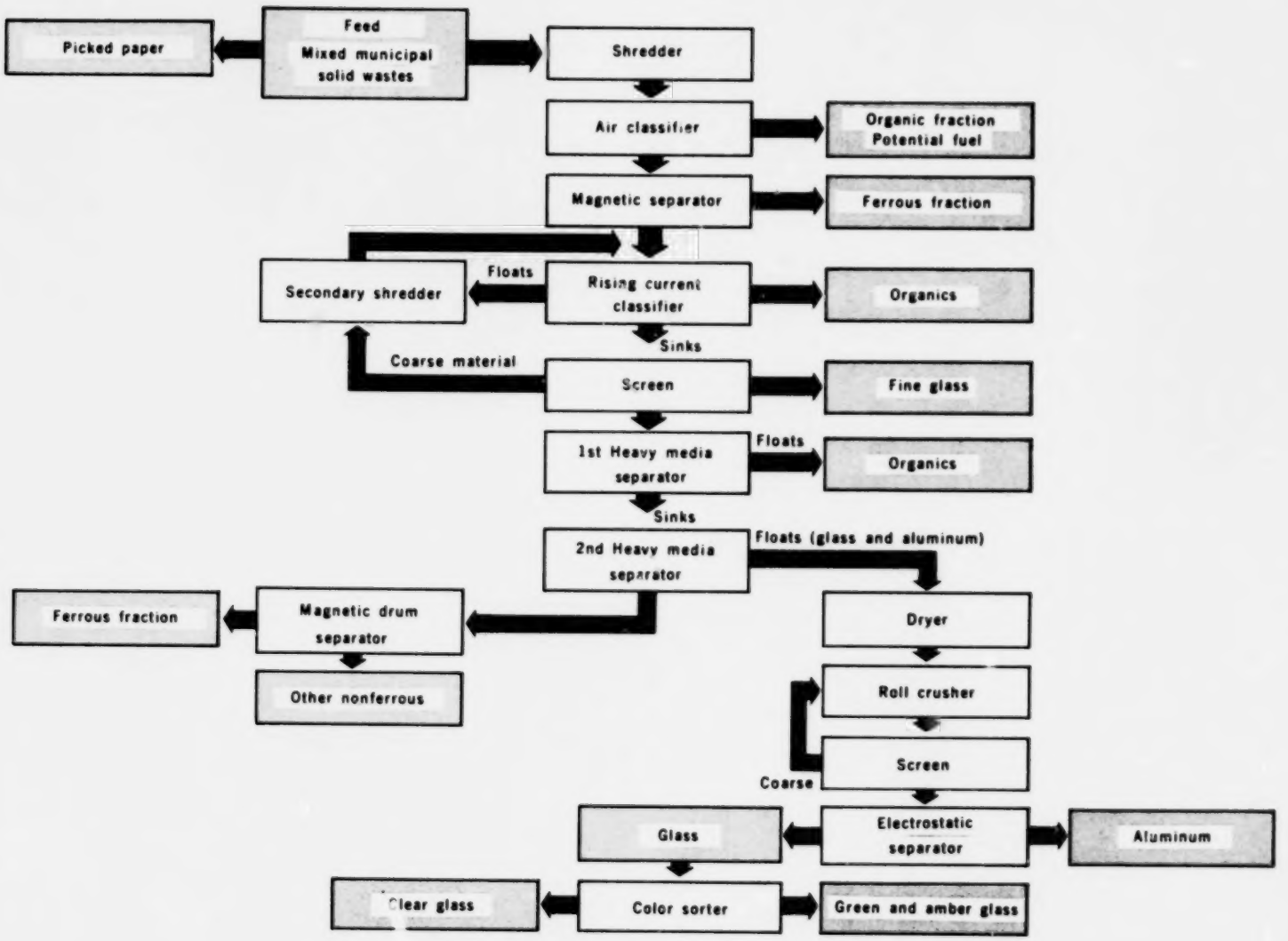

Figure 1. Processing scheme for separating materials from mixed refuse

Association of Recycling Industries, the cognizant trade association. Origin specifications are illustrated by designations such as "Genuine Babbitt-Lined Brass Bushings," "New Zinc Clippings," "Over-Issue News." The origin specification is not only a description of the material, but also often indicates limits of principal contaminants. This type of specification is essential for home and prompt scrap. It is also useful for materials recovered from municipal waste under certain circumstances, such as from voluntary recycling, hand separation, and sometimes, rejects from production of consumer items. This is reflected in the published specifications titled "Shredded Tin Cans," "New Aluminum Can Stock," and "Old Can Stock." (See Appendix A for examples of such currently accepted scrap specifications.) The published specification for "Incinerator Bundles" (Appendix A) describes the origin of a waste material from an established disposal process.

Origin specifications will not always be useful for products recovered from municipal refuse by combinations of mechanical and chemical processing. The reason for this is that the processing techniques are varied; many have been proposed and new ones are likely to be developed. At the present time, many new concepts for processes are untried. Thus, there is no large body of experience to make origin type specifications meaningful. Separation and recovery processes which have been proposed include steps which may not achieve complete separation and/or which may introduce a contaminant. An example of the latter is heavy media separation of

aluminum which may contaminate the product with iron and/or silicon. (This point is discussed later.) The existing origin type specifications do not make allowance for these circumstances and, therefore, cannot be used to assure quality and purity to buyers.

SECTION IV

METHOD OF APPROACH

The approach to the research reported here was to identify existing specifications for materials likely to be recovered from mixed municipal refuse, ascertain their usefulness by comparision with user (buyer) needs, and identify the contaminants likely to be found in the separated materials. The results of these activities were target specifications combining origin characteristics with chemical compositional limits which could be tolerated by the user industries.

NCRR had background information and knowledge of the composition of municipal solid waste (MSW) prior to starting this project. Literature searches had been made to review attempts at separating useful products from MSW. Visits were made to sites where separation equipment was being used, fabricated, or designed. Additionally, NCRR had performed several preliminary sampling studies. With this preparation, a previously proposed flow sheet (7)(13), shown in Figure 1, was devised to incorporate steps needed for separating a representative spectrum of materials which had the greatest apparent economic value per ton of MSW feed. This flow sheet is only an example of the way known unit operations could be combined to process municipal solid waste for resource recovery. The objective was to keep the concept simple and incorporate off-the-shelf processing equipment wherever possible (7).

Having identified the separation products of interest, NCRR personnel started a program of developing specifications by reviewing the technology of industries which might use the outputs. Concurrently, visits were made to companies which were potential purchasers of the recovered materials to discuss existing practices, requirements, and sensitivities to contaminants.

Some early efforts at writing standards based on first findings were submitted to appropriate organizations which have interest in specifications for materials. While little positive affirmation was received because of lack of supporting data, i.e., no operating separation plant, most organizations contacted expressed support for the specifications program.

Thus, while recommended specifications presented in this report are, at best, a start toward establishing acceptability of recovered products, the interest generated by this study should carry forward into future years. Hopefully, this effort will shorten the time which otherwise would have been required to design materials recovery plants and find stable viable markets for their outputs.

The research and related activities described here helped generate broad interest in specifications for materials likely to be recovered from MSW. One related result of this new interest was the founding of a new committee

within the American Society for Testing and Materials (ASTM), designated E-38, Resource Recovery. Another related result was the National Materials Conservation Symposium: I. Resource Recovery and Utilization, held April 29 to May 1, 1974, sponsored by the Environmental Protection Agency, the Bureau of Mines, the National Bureau of Standards, ASTM, and the National Center for Resource Recovery (14).

SECTION V

MATERIALS SPECIFICATIONS

In this section, each material likely to be recovered from mixed municipal solid waste is discussed from the standpoint of:

- background, including user requirements
- recommended target specification(s)
- analyses which support the choice of specification

The materials discussed are newsprint, old corrugated boxes, steel, aluminum, other nonferrous metals, glass, inorganic fines, and a refuse-derived fuel.

PAPER

Background

Shredding of municipal waste is almost always the first step in refuse processing for resource recovery (15), whether for wet or dry processing and for both materials and energy recovery systems (5). It was postulated (7) that clean newspaper and clean old corrugated boxes could be picked from the shredder feed conveyor provided householders (i.e., the disposer) bundled these materials before they were collected in a packer truck. Alternatively, the paper could be separately collected on the packer truck (16). The likely form of such recovered materials was compared to existing standards and specifications for secondary paper (2); the closest match between the standard grade

and the expected form of the recovered newspaper occurs when the paper meets the requirements for "No. 1 News." Similarly, recovered corrugated paper board could match the requirements for "Corrugated Containers." Both are standard grades of the Paper Stock Institute of America (2).

The published grades for No. 1 News and Corrugated Containers are listed in Table 1. A grade identifies and describes a material in a way such that the buyer knows the types of fibers and the condition of the material on receipt. In the secondary paper market it also implies the source of origin of material.

The specifications also list maximum permitted contents for prohibitive materials and outthrows. A prohibitive material is any included in a bale which if found in greater than the specified level would damage the paper-making equipment and/or destroy the quality of the final product. Examples are latex adhesives, magnetic inks, plastics, or asphaltic papers. Outthrows are contaminants which make the product unsuitable for consumption at the grade specified. Outthrows usually consist of materials which are compatible with the paper-making process but if found in amounts greater than the specified level will significantly degrade the quality of the final product. Examples are cloth bindings, chipboard, string bindings, and glassine. The effect of these materials, and pernicious contraries, have been discussed (17).

The Paper Stock Institute lists 24 grade definitions, most not applicable to paper in municipal solid waste, but several similar to No. 1 News. These several grades cover mixes consisting mostly of newspaper: Super News, Special News De-Ink Quality, and Over-Issue News. The specifications for these are also listed in Table 1 as an illustration of more exacting requirements for lower quantities of prohibited materials and outthrows. For example, none of either are permitted for the Over-Issue News category. It seems unlikely that householders could be educated to make their bundles completely free of outthrows, or foreign materials, and prohibitive materials, such as nylon hose or neckties (18). The No. 1 News grade permits more leeway; it should be easier to achieve at the expense of a lower selling price.

Other grades of paper are based on plant wastes or office wastes. The former are homogeneous such as envelope cuttings; the latter have limits on the amount of groundwood pulp permitted (2). These grades are not applicable to household wastes.

The possibility exists that bundled paper and corrugated picked from packer truck refuse (say from the feed conveyor belt to a shredder) can accumulate dirt, grease, or similar contaminants from the refuse. These possibilities are not provided for in the existing PSI specifications (2) but must be part of any specification for paper to be

Table 1

Illustrative Paper Specifications

#1 NEWS

Consists of newspaper packed in bales of not less than 54 inches in length, containing less than 5% of other papers.
Prohibitive materials may not exceed . . . . . 1/2 of 1%
Total Outthrows may not exceed 2%

SUPER NEWS

Consists of sorted fresh newspapers, not sunburned, packed in bales of not less than 60 inches in length, free from papers other than news and containing not more than the normal percentage of rotogravure and colored sections.
Prohibitive materials . . . . . None permitted
Total Outthrows may not exceed 2%

SPECIAL NEWS DE-INK QUALITY

Consists of sorted, fresh, dry newspapers, not sunburned. Packed in bales not less than 60 inches in length, free from magazines, white blank, pressroom over-issues, and paper other than news, and containing not more than the normal percentage of rotogravure and colored sections. This packing must be free from tar.
Prohibitive materials . . . . . None permitted
Total Outthrows . . . . . 1/4 of 1%

OVER-ISSUE NEWS

Consists of unused over-run regular newspapers printed on newsprint, baled or securely tied in bundles, and shall contain not more than the normal percentage of rotogravure and colored sections.
Prohibitive materials . . . . . None permitted
Total Outthrows . . . . . None permitted

Source: Paper Stock Standards and Practices Circular, Paper Stock Institute of America, August, 1972.

recovered from household waste. Dirt, grease, and similar contamination can be monitored by determining the amount of ash, water and solvent extractable materials in the paper by standard methods (19)(20).

Recommended Specifications

The specification for separately collected old newspapers and corrugated materials have been published (2). Tables 2 and 3 list the recommended target specifications for paper and corrugated materials, respectively, for materials recovered after being comingled with mixed waste in a packer truck. The bases for the values listed for prohibitive materials and outthrows are the PSI specifications (2). The rationale for values of ash and extractables will follow. At this time, no odor specification is included. It is possible that newspaper and corrugated mixed with refuse will pick-up undesirable odors. If the recovered paper is to be used for any products where this is important, additional points will have to be added to the specification (21). At this time, it is not recommended that the recovered paper or corrugated be used as furnish for chipboard for food packaging or any other product which may be sensitive to odor, taste, or possible contamination with extraneous metal ions. More work is needed to establish a basis for setting specifications on these points. The target specifications in Tables 2 and 3 are not meant to preclude separate collection of these materials (16) and sale subject to existing specifications (2) or others.

Table 2

Target Specification for Recovered Newsprint

Grade Title:	Recovered News (equivalent grades--Folded News, Regular News, Ordinary Folded News, No. 1 News)
Description:	Consists of folded newspaper including the normal percentage of rotogravure and colored sections
Packing:	Packed in bales of standard dimensions, not less than 54 inches long, approximately 1,000 to 1,500 pounds per bale.
Moisture:	Packed air dry
Prohibitive Materials:	Less than 1/2 percent
Outthrows:	Less than 2 percent
Water Solubles:	Less than 2 percent of the acceptable paper (Note a)
Organic Solubles:	Less than 2% of the acceptable paper (Note b)
Ash:	Less than 1% of the acceptable paper (Note c)

Note a: Determined by ASTM D-1162 or equivalent
Note b: Determined by ASTM D-1804 or equivalent
Note c: Determined by ASTM D- 586 or equivalent

Table 3

Target Specification for Recovered Old Corrugated Boxes

Grade Title:	Recovered Old Corrugated Boxes
Description:	Consists of used corrugated containers having liners of jute or kraft.
Packing:	Packed in bales of standard dimensions not less than 54 inches long; approximately 1,000 to 1,500 pounds each
Moisture:	Packed air dry
Prohibitive Materials:	Less than 1 percent
Outthrows:	Less than 5 percent
Water Solubles:	Less than 2 percent of the acceptable corrugated (Note a)
Organic Solubles:	Less than 2 percent of the acceptable corrugated (Note b)
Ash:	Less than 1% of the acceptable corrugated (Note c)

Note a: Determined by ASTM D-1162 or equivalent
Note b: Determined by ASTM D-1804 or equivalent
Note c: Determined by ASTM D- 586 or equivalent

Analyses

The target specifications in Tables 2 and 3 are based on the premise that the bundled newsprint and corrugated materials collected with other household waste, and delivered in a packer truck, could be recovered in a way to have the same properties as if collected separately. However, there is a possibility that mixing the paper and corrugated with putrescibles, wet garbage, and the other various contaminants in the truck, could cause deterioration of the fibers and introduce excessive dirt and prohibitive materials.

The above premise was tested experimentally. The City of Rockville, Maryland, has a separate newspaper collection, monthly. With their cooperation (22), prebundled newspaper at curbside was collected in the packer truck along with the regular semi-weekly refuse collection for that route. This was done twice--on a dry day and on a day following heavy rains. At the same time the paper was collected with the refuse this way, some bundles were picked from the curb at random, packed in heavy walled polyethylene bags, and set aside as controls, representing separate collection. After the crew completed their route, the truck was tipped separate from the regular collections (22) where the prebundled newspaper was picked with care to avoid the obviously dirty paper. No attempt was made to be highly selective in choosing clean paper. Samples were bagged; the remainder on one particular day was baled at a local scrap yard (23). The baled material (ca. 1,300 lbs.) was sent to a potential user, operating a roofing

felt mill; the bagged samples were analyzed in the laboratory. The report from the user was that the paper was "good stuff" (24).

The bagged samples were analyzed at the Gillette Research Institute, Rockville, Maryland (25). Analyses were made for moisture ash, solvent, and water extractables, tear and tensile strength (all using ASTM methods, ref. 19) and bacterial and fungal contamination. The paper collected in the packer truck mixed with refuse was compared to the separately collected newspaper and to unused newspaper stock as controls. The results are summarized in Tables 4a and 4b; details are given elsewhere (26). These results are the basis for the values for ash content and extractables in the target specification for No. 1 News. (No laboratory work was done using recovered corrugated but presumably the values could be chosen based on values for suitable controls.)

The laboratory examination of the paper showed the samples which were collected separately to be about the same as those collected in the packer truck judged from mechanical strength (as a measure of severe physical deterioration) and contamination -- with one exception.

The count of cellulolytic microorganisms (bacteria and molds, but principally the latter) was significantly higher for one sample collected in the packer truck, but not the

other, compared to controls. It must be pointed out, however, these organisms are aerobic and require moisture for growth; cellulolytic microorganisms are generally slow growing and slow acting. It is expected that in a paper bale, and especially at less than 10 percent moisture, these organisms will have no significant effect on the paper (26).

Table 4a

Summary of Findings--Ash, Organic Solubles,
And Water Solubles in Collected Newspapers

Property (method)	A curbside fresh,dry	B curbside overnight, dry	C comingled after dry day	D unprinted newsprint	E curbside, wet	F comingled after wet day
Ash, % (ASTM D586)						
Mean	0.51	0.38	1.12	0.53	0.45	0.50
Range	0.49-0.52	0.33-0.42	1.09-1.14	0.51-0.55	0.44-0.47	0.48-0.53
Org. Soluble, % (ASTM D1804)						
Mean	1.85	1.84	2.49	0.32	1.53	1.58
Range	1.84-1.86	1.83-1.85	-	-	1.46-1.59	1.57-1.59
Water Soluble, % (ASTM D1162)						
Mean	1.0	1.0	0.6	0.9	1.75	1.25
Range	0.90-1.15	0.71-1.24	0.54-0.67	0.86-0.90	1.53-1.96	1.24-1.25

Table 4b

MICROBIOLOGICAL CONTENT OF WET AND DRY NEWSPAPER[a] (ORGANISMS/CM^2)

	A	B	C	C[b]	D	E Wet	E Damp	F
Total Microorganisms	2.75	4.50	520	1425	1.25	178	1.00	0.50
Bacterial Spores	1.25	1.75	6.75	10.8	0.25	2.50	0	0
Total "Cellulolytic" Microorganisms	1.50	2.75	513	1414	1.00	175	1.00	0.50
Molds	0.25	0	13.3	18.0	0	158	0.50	0
"Cellulolytic" Bacteria	1.25	2.75	500	1396	1.00	17.5	0.50	0.50

(a) For identification of samples A-F, see Table 4a.

(b) This particular portion of sample "C" was intentionally hand-picked as obviously contaminated with household refuse.

STEEL

Background

The preponderant form of steel in mixed municipal refuse (mostly household sources) is cans - both tin plate and tin free steel (27)(28). A study (29) of iron and steel in MSW showed that cans (and related container steel) made up approximately 90 percent of the sample (500 lbs.) in one city and 94.6 percent of the sample (26 samples, average weight 13.9 lbs.) in another. The balance of the ferrous metal consisted of small miscellaneous items as hardware, metal castings, and nondescript bits of metal, most of which passed through a 1/2-inch screen. (Shredded can pieces were largely in excess of 1/2-inch in size). Some old bicycle and auto parts could also be recognized.

Given the apparent importance of steel containers in the magnetically separated component, it is necessary in writing specifications to focus on this portion.

There are several possible uses (3)(12) for recovered steel cans. The following were identified:

- substitute for iron ore as a charge to blast furnaces
- charge for steelmaking in the open hearth, BOF, Q-BOP furnaces or electric furnace
- remelt in electric furnace for continuous casting
- detinning
- raw material for ferroalloy production

- precipitation iron
- cast steel

Some requirements for each use, leading to specifications, are discussed. The general principles of each process are described in standard texts (30).

What is termed steel here is really a mixture of several iron containing metals to be recovered from municipal solid waste. Perhaps more accurately, the mixture of alloys should be termed "magnetic metals." Often, these are referred to as ferrous metals. It must be pointed out that not all ferrous (iron-containing) metals are magnetic.

Table 5 is the specification for Can Bundles issued by U.S. Steel Corporation. It is qualitative, perhaps too much so, but follows the same format for scrap as used by the industry for years (3). (See Appendix A for examples.) Apparently, the industry has not yet found a need for more quantitative specifications, in spite of the inherent weakness of any qualitative specification. Also, there are no generally accepted methods of statistically sampling large shipments of scrap steel so as to quantify the amount of contaminants.

Following industry examples (Appendix A), target specifications were written including qualitative descriptive

Table 5

Tin Can Bundles

Tin Coated Scrap Steel Cans, hydraulically compressed to charging box size not over 24" x 24" x 60" and weighing not less than 75# per cu. ft. Tin cans must be clean and free of all liquids and solids prior to baling. Tin free steel beverage cans with or without aluminum tops may be included. Must be free of aluminum cans, loose tin plate and terne plate scrap in any form, dirt, garbage, nonferrous metals (except those used in can construction), plastics, vinyls in any form, and other non-metallics of any kind.

Source: United States Steel Corporation
Purchasing Division
August 25, 1972

terms. In some instances, the specification could be related to alloy compositions of can stock and allowing for contaminants and physical form which could assist reuse in the applications listed above.

The basis for target specifications are conversations with various companies and the references cited. Among those contacted were major copper ore processors. Generally, like the steel industry, they do not purchase steel scrap to a quantitative specification. Like many other users of secondary materials, their practice is to purchase from dealers whom they know have shipped usable material in the past.

Recommended Specifications

It has been proposed that magnetic metals may be divided into heavy and light fractions using an air knife (31) or the entire portion may be shredded to minus two inch size, magnetically separated a second time, and shipped as a heterogeneous, loose mass (32). If the former, the heavy magnetic metals are expected to consist of a nondescript mixture of bar, castings, nuts and bolts, nails, rod, pipe, miscellaneous hardware, etc. Most pieces are expected to be less than 1 inch thick; generally, this fraction may also contain shredded portions of appliances. Smallest pieces are expected to be 1/2 inch -- largest 4 or more inches in size -- from the type of shredders used

for municipal refuse. Some pieces may contain small portions of bonded nonferrous metals, such as fasteners. The content of alloying and tramp elements is expected to total less than 2 percent by weight, including carbon, based on the analyses presented in the section following. The heavy, miscellaneous steel fraction may best be shipped loose. It's bulk density can not be predicted because of the heterogeneous nature of the mix.

The light fraction of a split will consist chiefly of cans, the principal source of ferrous metal in municipal solid waste. The cans must be reasonably clean and free of liquids and solids prior to baling so that bales, when sampled, will conform to the target specifications listed in Table 6. This specification is an attempt to quantify the specification of Table 5 to avoid non-specific terms. It must be pointed out that the numbers, specifically for non-metallic impurities, are based on a judgement of the capabilities of resource recovery equipment and are subject to revision as a quantitative basis is established. Also, the quantitative nature of the target specification in Table 6 is very much different from accepted industry practice (See Appendix A).

Steel cans prepared for sale to the copper industry for precipitation iron are described in the target specification in Table 7. Note that it is important for the

material to be of fairly uniform thinness such that the precipitation reaction is rapid and nearly complete for each batch. Baled cans are unacceptable for use in the copper cementation process because surface exposure is too limited to permit reasonable reaction time. There is no known way of quantifying these requirements. This specification (and others) remain qualitative.

A third possible specification for a light ferrous fraction applies to cans suitable for detinning (See Table 8). Such material must be relatively free of organic materials which unnecessarily consume the detinning solution. Unlike cans prepared for use as precipitation steel, those tin cans destined for detinning cannot be incinerated to remove organic contaminants; incineration causes the tin to diffuse into and alloy with the base steel (33) and thus be unrecoverable. Aluminum also unnecessarily consumes the caustic solutions used for detinning so is an unwanted contaminant. The content or organic materials stated in Table 8 is based on measurements (unpublished) of the organic content of the ferrous fraction processed by shredding and air classification prior to removal with a magnet.

Another method of preparing the magnetic metals from mixed, municipal waste for market, is to remove the shredded cans from the mix with a magnet, re-shred in a particular type of device to ball the steel in small pieces of high

bulk density, and again magnetically separate so as to leave behind aluminum ends and dirt (32). The material prepared this way appears suitable as feedstock for blast furnaces. Table 9 is a target specification for such material, based on reference (32).

Analyses

The light fraction of ferrous metals in municipal solid waste will consist chiefly of cans, both tin plate and tin free steel. These container stocks are made from cold rolled plate. Tin plate contains approximately 7-1/2 pounds of tin per ton (33). The tin free steel has a surface treatment of an ultra-thin layer of chrominum oxide (or similar material) to retard corrosion (34). The side seams are either welded or soldered with a low tin, lead solder (35). The cold rolled steel body stock may be one of several alloys, but has the general description (36):

Composition of Steel for Tin Plate - MR Grade

Element	Content
C	0.12% max.
P	0.02% max.
Cu	0.20% max.
Mn	0.20% to 0.60%
Si	0.01% max.
S	0.05% max.

In addition to the cold rolled steel can body stock, other materials used in can making are organic components (described later), lead and tin in solder, and aluminum.

Table 6

Target Specification for Can Bundles
Ferrous Scrap for Steel Making

Material:	Predominantly steel cans, magnetically separated from shredded municipal solid waste prior to incineration.
Alloy Composition:	All magnetic material, composition essentially similar to cold rolled steel used for can body stock but containing up to 4% aluminum that is normally used in can construction (notes a and b).
Non-metallics:	Less than 1% except for materials normally used in can construction
Bale Size:	Specified by user (note c).
Bale Density:	75 lbs./cu. ft., nominal, minimum
Cleanliness:	Free of organic materials and putrecibles so as not to present a health hazard.

Notes:
(a) Based on 31% of all cans produced as tin free steel and approximately 92% of these bi-metallic (aluminum ends). The weight of aluminum is 11.2% of the can weight. From these data, 3.2% aluminum in the bundles is a reasonable expectation. The 4.0% aluminum content listed above allows for seasonal variation, such as in the summer, when it is likely there will be more bi-metal beverage cans in the refuse.

Notes:

(b) Bundles must be free of all aluminum cans, loose tin plate, terne plate scrap in any form and other principal pieces of non-iron scrap.

(c) The cans must be free of draining liquids when baled.

Table 7

Target Specification -- Cans for Precipitation Iron

Shredded and crumpled cans, not folded on themselves (all magnetic material), loose packed density of 30 lbs./ cu. ft. maximum.

Scrap should consist of mostly cans so as to be of near uniform gauge and of maximum surface area. If not shredded to this specification, the cans may be prepared for shipment to a dealer and processor of scrap for the copper industry. If this is the case, the cans must be clean, free of heavy plate or wire, and shredded to a density to permit a 40,000 lbs./railroad car minimum shipment.

If prepared for shipment to a dealer-processor, the cans may be first incinerated to remove lacquers and organic contaminants but not enough to cause oxidation and metal loss to the point of flaking and loss in strength and integrity of the individual cans or to be detrimental to strapless baling.

Table 8

Target Specification for Cans for Detinning

Composition:	All magnetic can material, not incinerated
Form:	Loose flowing, whole cans or shredded to maximum surface area, free flowing (note a).
Rejects:	Balled or convoluted material blocking access of detinning solution (note a)
Organic Content:	Maximum 5%. Content may be used to determine price.
Aluminum Content:	Only from a normal mix bi-metallic cans, less than 4%. Content may be used to determine price (note b).

Notes:

(a) These are qualitative descriptions. Access of detinning solution, and permeability of cans to this solution, are qualitative judgements. Conceivably, this property could be quantified as the permeability (or drainage) of a specified volume of liquid through a column of cans of specified envelope dimensions. A specification for permeability can follow suitable experimentation and may have specifying this property may be more advantageous than specifying bulk density. The two are related but achieving a particular bulk density does not insure proper permeability.

(b) See Note a, Table 6.

Table 9

Target Specification for Ferrous Scrap for Blast Furnace Feed

Alloy Composition:	Similar to MR Grade cold rolled steel used for can stock but containing up to 4 percent aluminum and up to 20 percent assorted ferrous alloys (note a).
Plastics:	Visibly free except for plastics normally used in can construction
Dirt:	Less than 3% less than 10 mesh (note a).
Non-metallics:	Less than 1 percent (note a)
Physical Description:	Loose free-flowing pieces -- balled except for miscellaneous lengths of wire.
Piece Size:	95% by weight through a 1 1/2-inch screen.
Bulk Density:	In excess of 75 lbs. per cubic foot.

Note:
(a) The exact figures in these portions of the specification are subject to revision with experience. All are expected to be lowered on further analyses of material prepared as balled ferrous scrap for blast furnace feed.

Steel cans for beer and soft drinks frequently are made with aluminum ends of 5182 alloy so as to incorporate a tear-tab of 5082 alloy (37). The likely chemical composition of recovered steel cans may be derived from several literature sources (38)(39)(40).

Composition	Steel Beverage Cans	Other Steel Cans	Total for Composite
	%	%	%
Organic Coating or lining	.64	1.19	1.83
Aluminum	3.44	0.00	3.44
Lead	.49	1.20	1.69
Tin	.11	0.31	0.42
Steel	30.32	62.30	92.62

The content of aluminum is based on the premise that: (a) approximately 95 percent of beverage cans have aluminum ends, (b) soft drink cans and malt beverage containers comprise about 35 percent of total can shipments in the United States (40), (c) of the beverage cans, about 24 percent are made of tin free steel with aluminum ends, 72 percent of tin plate with aluminum ends, and approximately 4 percent made completely of tin plate (41).

The estimated composition (above) is consistent with the analytical results for melts of recovered cans (39) summarized in Table 10. However, tin is likely to decrease in future years as industry replaces tin plate with tin free steel (or aluminum) (38).

Because beverage cans have such great impact on the composite composition of ferrous scrap, and because use of these cans vary by season, it is necessary to examine possible variations in composition of the magnetic metals portion of municipal solid waste for each quarter of the year. Beverage containers (aluminum and steel) account for 39.3 percent to 45.4 percent of metals used in making cans (42) by season (See Table 10). It can be assumed that few companies would store cans for long periods of time because their bulk would make such a policy uneconomical. Thus, most cans are filled soon after manufacture. Furthermore, beer and soft drinks are usually fast moving items, i.e., have a short shelf life at the consumer sales level. With these considerations and applying the data in Table 11 to averages for the year, the aluminum content of recovered steel cans might increase 10-15 percent in summer months over winter months. Accordingly, the overall tin content might be slightly lower in the summer months as result of the effect of tin free steel beverage cans.

Recovered cans will contain organic materials from inks, liners, sealants, coatings and some contamination from other wastes.

Aerosol cans will contain non-metallic materials used for gaskets, valves, and buttons. One estimate (38) is that

1.9 percent of the weight of recovered cans is organic material. Examination of magnetically separated cans shows 1.1 percent by weight is organic coating and 5 percent of the total weight is other organic material (38).

The above discussion is based on expected national averages. However, the composition of the can portion of the recovered steel might vary considerably in a city where glass and/or aluminum beverage containers are in widespread use. The general effect of the aluminum, lead, tin, and organic material contaminants on reuse of the recovered cans, is discussed in turn.

Aluminum need not be a problem in steelmaking; it is frequently added to melts as a deoxidizing agent but at the end of the steel making process, not in the initial charge, as would be the case if aluminum is in the scrap. Should an excessive amount of aluminum be included, and oxidized to slag alumina, it can be detrimental (32). Lead is insoluble in molten steel and unlikely to interfere at the concentrations expected; reportedly, it oxidizes at steel melt temperatures and the lead oxide is collected as a dust from the stack emissions (43). Tin and copper in sufficiently high concentrations are tramp elements and are to be avoided in steelmaking (33). Organic materials burn-off during the melting of the steel.

Table 10

Reported Compositions -- Three Classifications of Ferrous Containers

Component	TFS Tin Free Steel	AE Aluminum End	TSE Tin Steel End
	%	%	%
Organic Coating	1.83	1.83	1.83
Aluminum	10.20	10.20	0.00
Lead	0.01	1.83	1.84
Tin	0.00	0.42	.48
Steel	87.96	85.71	95.85
Total	100.00	100.00	100.00

Source: E. J. Ostrowski, Recycling of Tin Free Steel Cans, Tin Cans and Scrap from Municipal Incinerator Residue, Presentation at 79th General Meeting, American Iron and Steel Institute, New York, May 26, 1971.

Table II

1971 Seasonal Variations In Metal Mix Beer & Soft Drink Metal Containers

(In base boxes of metal consumed; a base box is an area of 31,360 square inches of Metal)

	Year (000's)	First Quarter (000's)	Second Quarter (000's)	Third Quarter (000's)	Fourth Quarter (000's)
Beer & Soft* Drink Shipments	64,886	14,284	17,610	19,079	13.913
All other Cans	92,734	22,044	21,155	28,185	21,350
	157,620	36,328	38,765	47,264	35,263
Percentage Beer & Soft Drink	41.2%	39.3%	45.4%	40.4%	39.5%

*Includes aluminum and Steel

Source: Adapted from Containers and Packaging, U. S. Department of Commerce, July, 1972, pp. 23, 26.

They are undesirable as they add an additional load on air pollution control equipment and are a potential source of alloying carbon.

The likely effect of tin and copper inclusion in recovered steel, and estimates of their possible accumulation with repeated recycling have been reported. It has been estimated that after seven months the tin content of ingots would stabilize at about 0.03 percent and copper at 0.08 percent, assuming use of up to 50 tons of incinerated scrap in a 300 ton BOF heat (39). These estimates are based on analyses of steel from municipal incinerator residue which has a higher copper content than non-incinerated can scrap. Also, there are other conditions which could result in more or less tin accumulating in the ingots. The 0.03 percent and 0.08 percent figures have to be compared with the limits on these elements permissible for several uses of steel.

In sheet mill products for auto bodies, appliances, etc., the limit for critical forming grades is 0.01 percent tin, with a total residual (Cu, Ni, Cr, Mo, Sn) metals content of 0.16 percent. Some grades can tolerate more residuals but these result from failures to make the critical grades; they are not planned. Consequently, the inability to control and identify scrap quality makes it impossible to use non-critical grades of sheet mill

products as outlets for high residual scrap. Deliberately using high residual scrap, however, has an important effect upon the accumulated residuals and recycling of home scrap (that generated in the steel mill). Residuals in the latter are the averaged result of intake of residuals in virgin raw materials plus those in secondary materials (44).

In making base sheet for tin plate or TFS can body stock, the usual limit is 0.02 percent tin with a total residual limit of perhaps 0.25 percent. Copper is most critical, being limited to 0.06 percent in making type L tin plate. Some grades can tolerate 0.06 percent tin and 0.06 percent copper with regard to cold formability, but there are other limitations with regard to hot workability. For grades of sheet steels, which are pickled prior to coating, copper content is limited to 0.03 percent in order to achieve high pickling rates (44).

"Skelp" for making butt-welded and seamless tubes can tolerate 0.015 percent tin with the exception of electric welded tubes where the limit may be as high as 0.06 percent, depending on whether the pipe is to be hot formed. In most other grades, such as plates, bars, rod, and wire, tin does not usually appear on the specification. There is an anomaly here, however, for tin is critical in the range of 0.05-0.06 percent where the steel surface breaks up in the primary hot rolling (blooming mill and billet mill) operations. There is a synergistic effect between

residual copper and sulfur in the reheating fuel so that at 0.10 percent copper or less, 0.06 percent tin can be tolerated (45). These limits change when low sulfur fuel or an oxidizing reheating flame is used, but steel mills have not had to press the limits in this regard. Many products could tolerate higher tin levels, if they could get through the blooming mill with acceptable yield and surface quality (44).

There are two "background" effects with which mills contend:

(1) Hot metal (iron) from virgin raw materials typically contains 0.003 percent to 0.005 percent tin. In special cases, this may be appreciably higher.

(2) With about 30 percent scrap recycling within the steel mill itself, the permissible residual level of the typical product made dictates the permissible level of residuals in "home" scrap.

The typical top-blown oxygen steelmaking plant is operate in balance with 30 percent home scrap and 70 percent hot metal. Scrap preheating or bottom-blowing (Q-BOP) permits 40 percent scrap and 60 percent hot metal in oxygen steelmaking. Open hearth operations have a great range of flexibility; 30-10-60 as above is typical. However, open hearths can operate at about 30 percent home scrap, 40 percent purchased scrap and 30 percent hot metal. The extreme case, of course, is the electric

furnace using 30 percent home scrap and 70 percent purchased scrap (44).

These percentages are approximations and in practice are influenced by the silicon content of hot metal and the home scrap yield which varies by product and by process. For example, a plant working exclusively with continuous casting and making only merchant bar products should be recycling 20 percent scrap or less (44).

Recovered cans contain from 86 to 96 percent steel (Table 10) compared to a 65 percent iron content of pure Fe_3O_4, and to approximately a 25 percent iron content for taconite ores (before beneficiation). Thus, scrap steel could be charged as a high assay ore to blast furnaces if some other conditions were met. These include lack of persistent tramp elements, potential air pollutants, and a sufficiently high bulk density such that the furnace could be charged at reasonable cost with existing materials handling equipment. A bulk density of at least 75 pounds per cubic foot is needed for this purpose (46). In addition, the steel must be free flowing because of the nature of the operation of a blast furnace. The use of scrap steel in the blast furnace has been discussed by Ostrowski (32). Bulk density is also important for steelmaking, whether in open hearth, BOF, Q-BOP, or electric furnaces. Some of the reasons for this are ability to charge a sufficient weight in a

given time and maintaining a low surface to volume ratio, hence a low degree of oxidation with subsequent melt loss (47). If the scrap steel is to be used in an electric furnace feeding a continuous strand casting machine, the aluminum content in the steel becomes critical. Aluminum is not easily oxidized in the melt in an electric furnace as it would be in other furnaces, but does readily oxidize at the continuous casting nozzle. The resulting oxide, or dross, can clog the nozzle (48). Although methods have been developed to avoid this, they are expensive to install and operate (49).

Tin plate steel cannot be detinned by heating. At relatively low temperatures, tin alloys with iron (33). Detinning is accomplished by dissolving the tin (and any accompanying aluminum) in hot caustic solutions (50). The recovered cans must not be balled, or otherwise flattened to a form such that the caustic cannot reach the tin, or cannot easily drain after the detinning process (51).

Little information seems to be available that could be the basis for choosing a specification for the ferroalloys industry. On contacting representatives of this industry, we learned that some processes are geared to a particular source of scrap and that the processors would not be interested in discussion of needs and uses for other sources. (These discussions were before the acute scrap shortage of 1974).

The use and needs of precipitation iron in the recovery of copper from low-grade ores has been discussed (52). Almost any form of scrap capable of being readily and uniformly attacked by sulfuric acid is usable.

Scrap steel cans can be utilized for cast iron and cast steel. The properties of the melt meet commercial standards, based on laboratory results (53)(54). Tentatively, the target specification can be the same as for blast furnace use, pending publication of research results using such scrap in foundries (45).

No specification was considered for steel recovered from incinerator residues for several reasons. If improperly incinerated, the cans might be too oxidized, even for use as a precipitation iron (55). Also, such cans pick up trace amounts of copper (56) making the steel "short" and unsuitable for rolling (30). The steel industry has difficulty utilizing steel recovered from incinerator residues (57). Cans recovered from municipal waste cannot meet the specifications for form and density of standard scrap designations, such as No. 1 and No. 2 bundles described in Appendix A. Properly prepared and baled, can bundles come closest to No. 2 bundles (different from No. 2 Heavy Melting), but by description are not No. 2 bundles.

The content of aluminum, tin and lead in all magnetic can bundles need not be detrimental to steel making processes (43) if sufficient hot metal is available to dilute the

tramp elements. The amount needed will depend on the targetted alloy end use for the mix. It may be possible that reshredding of bi-metallic cans, followed by magnetic separation, can be used to reduce, but not eliminate, the aluminum content (32).

Scrap steel from municipal solid waste is potentially useful in various steelmaking processes and other traditional uses of scrap. The available information concerning the effect of alloying and tramp elements on these uses does not permit a "cookbook" approach to specifications. The art of steelmaking is too complicated for gross simplifications regarding scrap utilization. The information above is included for background guidance. Many target specifications will have to be negotiated between buyer and seller depending on the end use intended for the scrap. The use of resource recovered steel scrap in steelmaking, and the iron and steel foundry industry, has recently been reviewed, including a discussion of the effects of contaminants (45).

ALUMINUM

Background

Aluminum alloy properties and metallurgy are extremely sensitive to the concentration of alloying and tramp elements (58) (59). There are more than 150 different recognized (registered) wrought alloys and more than 75 different casting alloys of aluminum designated by the Aluminum Association (60). Producers mix standard proportions of alloying metals with pure aluminum (primary metal) to create the alloys. They also add scrap of known composition, when appropriate, and adjust input of alloying metals accordingly. "Home scrap" is preferred, but primary producers also use purchased scrap. Reportedly, about 20 percent of aluminum sold is from secondary sources (61).

Secondary smelters account for almost 80 percent of scrap aluminum purchases from dealers (61). They may use new scrap (turnings, clippings, etc.) or old scrap (such as castings, sheet, and pistons). The smelters blend scrap from many sources, diluting aluminum which contains unwanted alloying metals.

Currently, scrap buyers recognize at least eighteen grades of aluminum (1) (3). Classification is made chiefly by source and physical description rather than by elemental analysis. In sharp contrast, alloys of all

sorts and of primary and secondary casting alloys are designated by chemical composition.

If aluminum recovered from municipal waste is to be reused by the primary aluminum producers, it must be processed to fall within one of the three broad categories of wrought, extruded, or cast products. The reason for this is that this categorization determines price. All three types could be utilized by secondary aluminum smelters; the highest potential value for aluminum separated from municipal waste appears to be for re-use in new melts of wrought alloys. Obviously, the material sold should not be contaminated with other alloy types which may interfere with this use.

Aluminum in mixed municipal refuse may consist mostly of beer and beverage cans (70 percent in one city) depending if that is the predominant form of packaging in the marketing area (62). The remainder is miscellaneous foil, extrusions, and castings. The likely composition of alloys used in consumer products are listed in Table 12. Sensibly, then, the aluminum might be recovered in two fractions: one consisting of mostly beverage cans and foil and the other consisting of miscellaneous extrusions, castings, etc. The reason for including foil with cans is that foil is either 1100 series alloy (commercially pure) aluminum or 3000 series alloy, such as 3003. Both materials would be diluents for the 3004 alloy

Table 12

Examples of Aluminum
Items Found
In Municipal Waste

Likely Alloy Used	Products	Nominal Chemical Composition (Balance Al)
1100 Series	Cooking utensils Hair curlers Lightweight kitchen foils Product wrappings	99.0% Al "Commercially pure"
3003	Cooking utensils Toys Pie Plates Heavy foils	1.2% Mn 0.6% Si 0.7% Fe
3004	Lamp bulb bases Beverage container bodies	1.2% Mn 1.0% Mg 0.3% Si 0.7% Fe
5005	Annodized decorations Appliances	0.8% Mg 0.4% Si 0.7% Fe
5050	Appliances General Purpose Tubing	1.4% Mg 0.4% Si 0.7% Fe
5182	Beverage container tops	0.35% Fe 0.35% Mn 4.5% Mg 0.2% Si
5255	Automotive trim Lawn furniture	2.4% Mn
5257	Automotive trim	0.4% Mg
6063	Window frames	0.7% Mg 0.11% Si 0.35% Fe
6463	Automotive trim	0.7% Mg 0.2-0.6% Si

Table 12 (continued)

Examples of Aluminum
Items Found
In Municipal Waste

Likely Alloy Used	Products	Nominal Chemical Composition (Balance Al)
(Castings)		
13	Typewriter frames	12.0% Si 2.0% Fe
43	Architectural Ornamentation	5.0% Si 2.0% Fe

Source: Adapted from P. Farin, G. Reibsamen, Aluminum, Profile of Industry, McGraw-Hill, New York, 1969.

used for aluminum can bodies and 5182 alloy used for can ends (63). Alloys 3004 and 5182 melted together yield a compostion sufficiently similar to 3004 that a mixed metal of the two can be used to produce new 3004. Some magnesium is lost on re-melting recovered cans (64).

Recovered aluminum must be free of sand, grit, and particularly glass. At the melt temperature, aluminum will reduce the silica in glass to silicon, which will alloy, and cause the melt to be off-spec. Higher silicon-containing alloys are not desirable for wrought products but find use as extrusion or casting alloys (63) (64). Iron content is similarly a problem and such contamination must be kept low. Likely, this could be accomplished through proper processing when recovering the aluminum.

Carbon does not alloy with aluminum (58). Organic materials in recovered aluminum will burn-off in the furnace and either cause an additional load on the air pollution control equipment or be included in the dross (slag). In either case, organic materials are contaminants in that they add to processing costs.

The aluminum must have a low surface to volume ratio (i.e., a high bulk density), hence baled or briquetted to avoid melt-loss during re-smelting (63) (64). For similar reasons, the specification must include a limit on fines.

Specifications

Aluminum specifications were pursued with two primary aluminum producers. Their acceptable limits of alloying and tramp elements are different. As a result, two specifications for the aluminum fraction consisting mostly of cans and foil are proposed. Presumably, the specification calling for lower contents of alloying elements (especially Si and Fe) is for metal which will be reused in wrought products. No specification is needed for the other fraction of aluminum - the miscellaneous extrusions and castings. Its composition is expected to vary over wide limits. Aluminum is a high value commodity and even this down-graded variable composition scrap should be saleable at a reasonable price.

Tables 13 and 14 are the target specifications for the can and foil fractions. The following notes apply to both tables. The scrap can be shipped either loose (in covered trucks or railroad cars) or loosely baled or briquetted to a maximum density of 30 lbs./cu. ft. Aluminum may be passed through a hammermill, rod mill, grinder, or other kind of shredder, but piece size must be such that 100 percent is retained on a 12 mesh screen. The metal should be screened to reduce fines such as dust, dirt, sand, etc. The aluminum must be free of heavy media, dried prior to shipment, and not obviously corroded. Analyses will be made on the melt of a total shipment or

Table 13

Chemical Composition Limits of Al Scrap

Target Specification for Reuse in Wrought Alloys

Element	Maximum Contents[a] Grade I	Notes
Si	0.3	b
Fe	0.7	
Cu	0.40	
Mn	1.50	
Mg	2.00	
Cr	0.10	
Zn	0.25	
Pb	0.04	
Sn	0.04	
others	0.12	c
dirt, fines	1.0	d
loose organics	2.0	e
Al	remainder	f

Notes:

(a) Downgrading of the selling price can be in proportion to the extent of the dilution with primary metal necessary to achieve the composition limits. Maximum permissible dilution will be 50 percent.

(b) As alloyed.

(c) Less than 0.04 each

(d) Maximum quantity minus Tyler screen size No. 12.

(e) Not including can coatings.

(f) For samples of melt loss exceeding 10 percent, the selling price may be further downgraded in proportion to the melt loss.

Table 14

Chemical Composition Limits of Al Scrap

Target Specification for Possible Reuse in Cast and Secondary Alloy Products

Maximum Contents

Element	Wt.%
Si	1.0
Fe	1.0
Cu	2.0
Mn	1.50
Mg	2.00
Cr	0.30
Zn	2.00
Pb	0.30
Sn	0.50
Others	0.12*
Fines	3.0
Al	remainder

*Less than 0.04 each

Note: Permitted maximum contents of alloying and tramp elements of a grade for use in secondary products are listed above. Any scrap shipped, which upon analysis fails to meet specifications, shall be rejected and at seller's option be returned to seller at his expense or sold to buyer at a reduced price, to be negotiated.

Metal not meeting the composition limits stated will be down-graded to a category where the selling price will be negotiated on an individual shipment basis.

Table 14 (continued)

Note:

The scrap aluminum in mixed municipal refuse must be separated from all other materials. If the material is reclaimed using dry processing following thermal treatment of the refuse, it must be baled to a minimum density of 30 pounds per cubic foot. If the aluminum is separated from raw refuse or if wet processing techniques are used to separate the aluminum, the aluminum must be shredded or dried prior to baling. The shredded material must pass over a U.S. Standard 12 mesh screen to reduce fines (dust, dirt, sand, paint, etc.). Fines must not exceed 3% of gross weight. The finished product must be baled or briquetted to a minimum density of 30 lbs./ft.^{3} Analyses will be on the melt of a total shipment.

on a statistically determined sample of that shipment (there is not yet any accepted way of such sampling) by a method such as ASTM E-34-68 or equivalent.

The chemical analysis of the melt from the scrap batch will determine the grade of that scrap. The magnesium composition limit is calculated on a 75:25 by weight mixture of alloys 3004 and 5182, respectively.

Analyses

In order to verify the proposed specifications, aluminum samples which were hand picked from the municipal refuse in Tampa, Florida, and New Castle County, Delaware, were chemically analyzed (65). It was previously determined (62) that aluminum comprises about 1.0 and 0.6 percent respectively of the municipal waste in these two locations. The difference is accounted for in that Tampa's waste stream contains a greater proportion of aluminum beverage cans.

The Tampa sample was divided into two portions: (a) cans and (b) mostly formed containers, including miscellaneous items such as ice cube trays and a water pitcher. The results of chemical analyses of these portions are shown in Table 15. The high iron content in formed containers need not be considered typical because magnetic separation would be expected to remove steel to lower levels than hand separation. This is confirmed by the Tampa sample

which was mostly cans. It was magnetically separated and analyzed; the iron content was 0.5 percent.

The sample hand picked from New Castle County, Delaware, was mostly formed containers and foil, with some pieces of screen. The average chemical composition is shown in Table 15. Again, the high iron content is probably due to steel cans which were not removed in the hand-picking. The analytical results support the use of calculated average alloy compositions in determining the chemical specifications of recovered aluminum.

Also shown in Table 15 are the analyses of aluminum recovered from air classification and heavy media separations (66). In spite of using ferrosilicon as the media, a mineral which could cause contamination of the aluminum with both iron and silicon, and in spite of the solubility of this mineral in molten aluminum (67), the aluminum recovered this way lends confidence that the specifications of Tables 13 and 14 can be melt with careful processing. Other means of recovering non-ferrous metals have been described (68).

Table 15

Chemical Analyses

Aluminum From Municipal Refuse

Element	Tampa Formed Containers	Tampa After Mag. Separated	New Castle Co., DW (Mixed Packaging)	Metal Separated by Heavy Media, ref. 66
Si	0.2	0.2	0.2	0.18
Fe	3.0	0.5	1.2	0.51
Cu	0.2	0.1	0.1	0.10
Mn	0.3	1.0	0.5	0.82
Mg	0.1	1.2	0.02	0.45
Cr	0.03	0.01	0.00	0.01
Ni	0.02	0.00	0.00	0.00
Zn	0.05	0.08	0.08	0.04
Ti	0.01	0.02	0.02	0.03
V	0.00	0.00	0.00	-
Pb	0.02	0.00	*	0.01
Sn	0.01	0.00	0.00	0.05

*Pb was 0.00 in one sample and 0.6 in second sample.

Analyses performed by L. C. Blayden, Alcoa Technical Center, Merwin, Pennsylvania.

OTHER NONFERROUS METALS

Background

Based on analyses of incinerator residues (69), the expected composition of the nonferrous metal fraction (excluding aluminum) of municipal wastes is:

Metal	Expected Wt.%	Range Wt.%
Cu	55	47-70
Zn	35	33-40
Sn	1	-
Pb	2	0.5-0.3

When sampling waste it is apparent that the nonferrous fraction consists of every conceivable material and form (62), including keys, coins, light bulb sockets, pieces of plumbing fixtures, and all sorts of hardware (70). The secondary materials industry has developed a large number of specifications to cover such materials from industrial wastes (1) (3), but for the most part, these specify materials according to their origin. Examples are the several specifications for copper, including copper wire, heavy copper (clippings, pipe, tube, etc.), light copper (bottoms of kettles, boilers, roofing, etc.) and automobile radiator cores. The existing NARI specifications (1) may be applicable to the nonferrous metals in mixed municipal waste after separation and sorting. They are not applicable prior to sorting.

The mixture of nonferrous metals in the refuse after sorting is somewhat analogous to the mixture of nonferrous metals resulting from auto shredding. Conversations with auto shredder operators (71) indicated that

the nonferrous concentrate from shredders consists of mixed nonferrous metals, including non-magnetic stainless steel, heavy rubber, dirt, glass, and some magnetic material missed during the prior processing. The price paid by the processing or separating plant for this concentrate is on the basis of the nonferrous metal content recovered. No value is assigned to magnetic materials nor is an extra charge made for disposing of the non-metallic materials. Stipulations are usually made that the seller will not hand-pick copper or other red metals. The processor makes deductions from the contained nonferrous metal content of about 4 percent for moisture and 10 percent for smelting loss of zinc. There is an additional deduction in the price paid if the feed is particularly low in metal values or otherwise so "dirty" that it requires extra processing. The mixture of nonferrous metals from mixed municipal refuse is expected to contain little dirt (7). (The likely contaminants will be stones and gravel.)

Processing of the mixed, nonferrous metals from auto shredder scrap results in some losses, approximately 20 percent -- less than would be obtained from hand-picking. This can be accounted for as a 15 percent melt and oxide loss from zinc sweating and a 6 percent loss due to less than 1/4 inch fines. The mixed, nonferrous metals recovered from municipal waste should be an ideal feedstock for a processor of auto shredder scrap.

Because of the operating nature of this industry, a satisfactory specification for mixed non-ferrous metals may only need be qualitative.

Recommended Specification

A proposed specification for mixed, nonferrous metals in municipal waste is given in Table 16.

Analysis

Samples hand picked by NCRR personnel from municipal waste contained diverse mixture of nonferrous metals. It is impossible to quantify what may be in them or to predict composition in advance. One sample of this mixture, recovered by heavy media processing (66), contained 9 percent by weight stones. It was otherwise free of non-metallic materials. Figure 2 is a photograph of this mixture.

GLASS

Background

Recovered glass can be re-used in containers, in secondary products, such as building materials, or as an aggregate substitute such as in Glasphalt^{R} (72). The requirements for each use differ widely.

Raw materials for glass container manufacture are carefully controlled so as to maintain batch-to-batch reproducibility (73). The feedstock or "batch" to the

Table 16

Target Specification for Other Nonferrous Metals

Contents:	Miscellaneous nonferrous metals, including non-magnetic stainless steel
Size:	100% retained in 3/16 inch screen (note a)
Cleanliness:	Minimum 80% by weight metal (note b)
Form:	Loose, not balled and dry

Notes:

(a) The mixture may be screened to separate pieces too small for handpicking of red (copper bearing) metals, approximately 1 1/2 inches in size. Smaller sized pieces are processed and recovered by other than handpicking.

(b) Price may be down-graded on basis of content of non-metallics. Subject to negotiation.

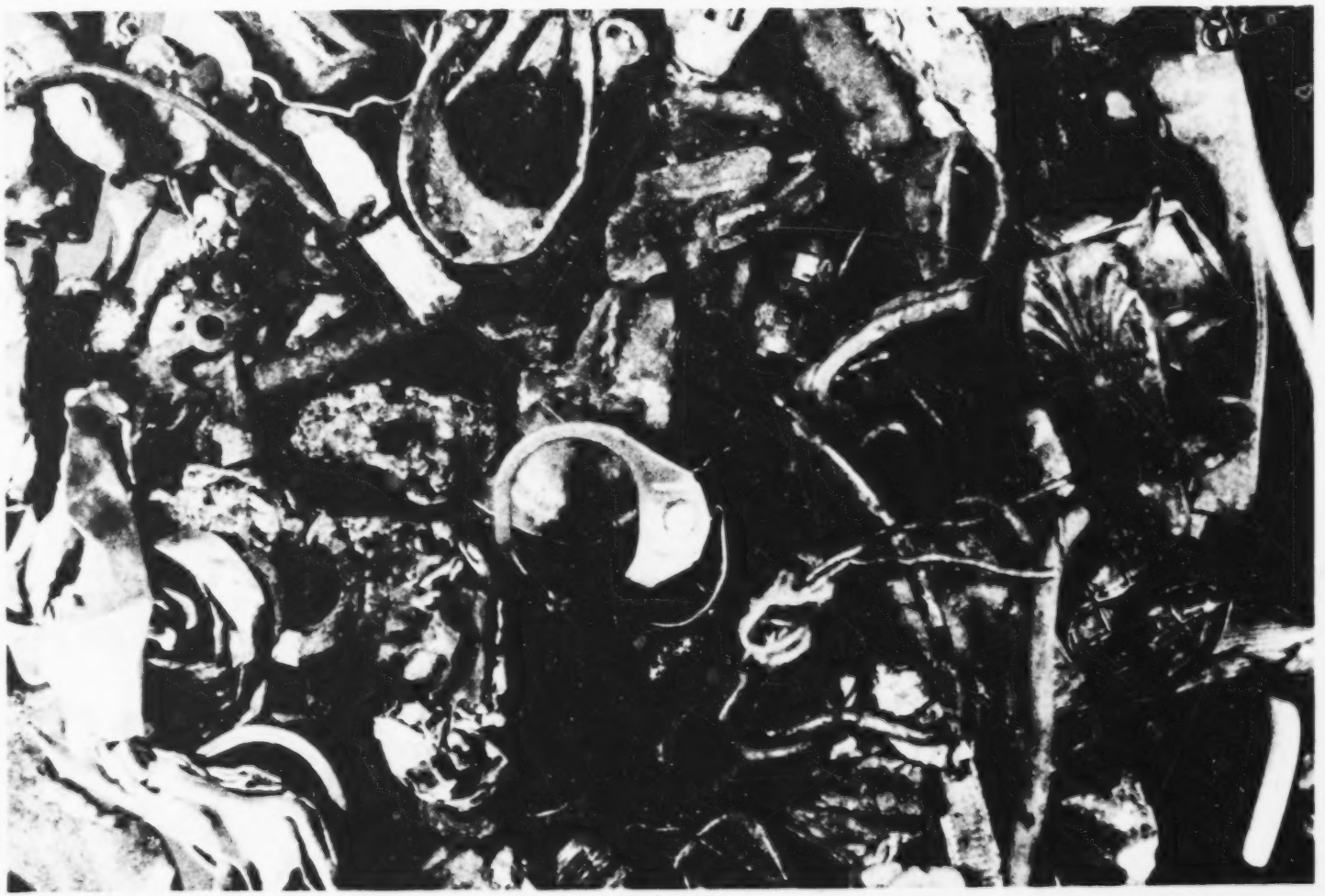

Figure 2. Sample of mixed non-ferrous metals recovered from municipal solid waste by processing through heavy media (66). This sample contained 92 percent metal; the remainder was mostly stones.

glass furnace (or tank) must be free of refractory particles which will not melt; they are the cause of "stones" in the glass (a ceramic inclusion and a possible point of stress concentration which has an undesirable appearance and may cause weakness and bottle breakage) (74)(75). A bubble in glass, known as a "seed," also causes unaesthetic appearance and can lead to weakness. Recovered glass can cause both stones and seeds if not processed properly. For example, bottles made from a batch containing 4.8 percent glass cullet supplied by Bureau of Mines Incinerator Residue resource recovery plant, apparently had more metallic contaminants, which are likely to cause seeds, than were in standard glass making materials. These bottles had up to 48 seeds per ounce compared to 5 or 6 seeds per ounce for the controls. This test of the recovered glass was on full scale production machines (76). No mention was made of stones in the test glass.

A potential source of stones is aluminum. At glass melt temperatures in the absence of air, aluminum reduces silica to silicon, which is refractory and forms the stones (75).

Additionally, glass must be free of ferrous materials which will change the glass color. Amber and green glass contain varying small amounts of iron in the Fe II and Fe III oxidation states, and chromium in

several oxidation states, which will affect the color of the final glass when added as cullet. Chromium is especially troublesome, because its oxidation states range from +3 to +6, each of which impart a different shade of green.

Reportedly, it has been industry practice to use cullet in the glass formula of from 15 to 20 percent by weight (73). However, subsequent work, perhaps in anticipation of greater availability of cullet, has shown that as much as 100 percent can be used in production melts, under appropriate circumstances (77).

Several colors of glass can be recovered from mixed municipal waste. About two-thirds of the glass produced for containers is flint or clear (74). Georgia Green (light green) is used for the familiar Coke^{R} bottle; Emerald Green is the deeper color of other soft drink bottles; Champagne Green is the deeper color of wine bottles: amber glass is largely used for beer bottles. Also, when refuse is sampled, there are always small amounts of blue and opal glass. The mix between amber and green seems to depend on the part of the country, with more green on the west coast than the east. It is likely that a materials separation plant operating on mixed municipal refuse will be able to separate flint (containing some Georgia green) from mixed colors and leave behind a mixture of amber and green (78). It

may also be possible to separate the green from amber, but there will always be a fraction of color-mixed (7), which can be used in the manufacture of new containers (77).

To date, there is insufficient experience using glass for building products to be able to write specifications. Some of the uses seemingly do not require a clean product (72). Use in brickmaking may require specifications for particle size and organic content (79).

In order to provide guidance for development of MSW separation systems, the Glass Container Manufacturers Institute developed preliminary guideline information which would describe a typical cullet quality acceptable for use in glass container manufacturing furnaces (80) and reflects manufacturing experience. The bases for this specification have been described (75).

These quality guidelines for cullet were designed so that the material could be used as full substitution for in-plant cullet. In other words, large percentages of this cullet could be placed in the batch without potential damage to the furnace and without lessening the quality of the finished product. (Along with guideline information, GCMI also recommended quality control methodology to assure proper preparation and examination of the cullet samples.)

The purchase of cullet in the past commonly called for glass which was "clear, color-sorted, and free of metals." It was relatively easy to follow these instructions because much of the cullet was obtained regularly from brewers and bottlers by cullet dealers, some of whom processed or beneficiated the cullet meet customer requirements. Increasing labor costs over-priced these sources so that less and less cullet was purchased.

The cullet generally was crushed for handling and washing, and left in the $\pm$3/4 inch size range for easy identification of color and such foreign material as stones and metals, as well as to facilitate melting in the batch. Generally, sizes over 2 inches cause handling problems for container manufacturers. Finely ground materials also present problems of storing and handling the materials. In addition, color identification would be difficult, if not impossible, for sizes less than about 3/16 inch in size. Small size cullet presents another problem because this condition prevents good drainage. A cullet pile or sample should show no drainage, but small sized cullet would retain a higher percentage of water if only by capillarity.

Other properties of purchased cullet can be designated based on manufacturing experience in the industry. The maximum amounts allowed are listed as the percentage fraction, dry weight basis, in Table 17.

Table 17

Guidelines for Cullet as a
Direct Replacement
for In-Plant Cullet

Metals: maximum size 1/4 inch: magnetic, 0.05 percent non-magnetic, 0.015 percent.

Organics: maximum amounts: paper and plastics, 0.05 percent other, 0.05 percent

Solid Inorganic Material other than Metals:

Maximum size 1/4 inch. Refractory, 0.05 percent. Note: When the sample is believed to contain refractory inorganic material, the cullet sample will be subjected to the following added specifications: A one-pound sample may not contain more than 2 particles in the -40+60 mesh size range.

Mixed Color Glass

Color of Cullet	Color of Batch		
	Amber	Flint	Green
	Percentage cullet in batch		
Amber	90-100	0-5	0-35*
Flint	0-10	95-100	0-15
Green	0-10	0-1	50-100

*Does not apply to Ultra-Violet absorbing Emerald Green glass

Source: Derived from information supplied by J. Abrahams, Glass Container Manufacturers Institute, Washington, D.C., 1973.

The guidelines of Table 17 were the basis for negotiating the target specification of Table 18 (81). The principal difference is in the content of organic material. The specification for color sorting is based, in part, on the expectation of electronic color sorters (78)(82).

There have been recent tests of the ability of available equipment to recover glass to the specifications of Tables 17 and 18 (78). Preliminary results are that these specifications were not achieved with the equipment described. At the same time, glass melting research indicated a need for decreases in the permissible level of refractory impurities. The subject is still open and basis for discussions ongoing within ASTM Committee E-38.

Analyses

The requirement in the target specification for counting the number of refractory particles translates into a maximum refractory content of about 0.0003 percent by weight refractories. When glass was separated from shredded municipal refuse (27), it was noted to contain many small pieces of egg shell. These are calcium carbonate, which will flux, and is a permissible foreign material in cullet (76).

There have been some tests of individual processing steps as a means of preparing glass to the target specification of Table 18. Heavy media separation is capable of

Table 18

Target Specification for Cullet for Use in Container Manufacture

Liquid	Cullet to show no drainage from sample. The cullet must be non-caking and free flowing.
Organic	Maximum 1.0%
Sizing	0 on 2" bar screen and be retained on a 100 mesh screen.
Magnetic Material	Less than 0.5% maximum size 1/4".
Non-magnetic Material	Less than 0.02% above 60 mesh.
Ceramic	.05% maximum size 1/4".
Refractories	One pound sample may not contain more than 2 particles greater than 40 mesh in size, nor 20 particles in size range between 40 and 60 mesh. Future glass container melting research may indicate a greater tolerance for refractory particles, in which case, the specification may be altered.
Mixed Glasses	Cullet that does not meet the color specifications below, will not be considered color sorted.

	Cullet		
% in Cullet	Amber	Flint	Green
% Amber	90-100	0-5	0-35
% Flint	0-10	95-100	0-15
% Green	0-10	0-1*	50-100

*Flint cullet can contain either 1% emerald green, or 10% Georgia green, or combinations of both with 1% Georgia green equivalent to 1/10% Emerald Green.

separating glass from extraneous matter and some stones (83). In other work (27), glass was separated from shredded municipal refuse originating in New Castle County, Wilmington, Delaware by screening the refuse portion that sank in water. Wet screening and separation on a Wilfley table (27)(84) were the only techniques used to prepare what appeared to be clean glass. Organic contamination was tested by loss on ignition at 475°C., and found to be from 0.6 to 1.2 weight percent. (At temperatures higher than this there are weight losses due to loss of water of hydration, CO_2, etc.) This sample was then analyzed for content of refractory particles. The results are summarized below showing a great excess of refractories above permitted levels by the specification.

Refractory Particles Per Pound of Original Sample

Material	+40 Mesh	+60 Mesh
Sillimanite	96	120
Corundum (Single Crystal)	12	48
Corundum (Tabular)	60	--
Unidentified White Ceramic	72	--
Totals	240	168

These results emphasize how readily refractory material can be included in the glass fraction.

INORGANIC FINES

Background

Because almost all proposed MSW processing concepts start with a size reduction (shredding) step, it is reasonable to assume and it has been found (27), that friable materials, particularly glass, will be reduced to small pieces. Contacts with representatives of user industries indicate that most do not want fines. For example, in the glass industry cullet sized larger than 100 mesh is usually required for reuse in the furnaces (74) (75). Additionally, if color separation is performed to upgrade the glass, sorting equipment limitations (78) (82) currently prevent classifying particles less than 3/16 inch in size. A study of the outputs of MSW shredders in eight selected cities indicate that as much as 85 percent of the glass content is reduced to minus 3/16 inch size (27).

Water sink-float separation (27) of shredded MSW samples showed that inorganic fines (principally glass) will be the major component among solids passing screens following water elutriation. The material passing through will have to be landfilled if it does not find market acceptance. Best possibilities for utilization appear to be as sand and gravel substitutes.

One market opportunity may be as an aggregate ingredient in asphaltic paving mixes. Much work has been done in trying various mineral tailings and dusts in asphalt road surface mixes at least as long ago as 1921 (85).

More recently, waste glass has been used with some success in road construction (86).

While use in standard pavement offers large volume outlets for finely divided inorganic stones and other materials, their sales worth cannot be high because they compete in this application with inexpensive materials. Other opportunities may exist with small potential volume, but with the advantage of higher selling prices. Perhaps the more promising possibilities are as "pea gravel" in porous concrete (87) and as a clay substitute in brick making (79).

Target Specification

Considering the relative uncertainty about ultimate use, only a general specification for inorganic fines can be written. It is presented in Table 19.

While processing may conceivably upgrade the inorganic fines, it is unlikely that the added costs can be justified by significantly higher market values. With this in mind, the target specification of Table 19 was written for essentially a by-product which could be used in applications where impurities could be tolerated, for example, paving, brick-making, etc.

Little difficulty is expected in using the inorganic fines in brick manufacture. U.S. Bureau of Mines has successfully produced quality bricks substituting pulverized incinerator residue (glass-rich and metal-free)

Table 19

Target Specification

For Inorganic Fines

As a sand and fine gravel substitute, particle size distribution will be such that 98 percent by weight will pass through a 3/16-inch screen. Minimum size 200 mesh to avoid dusting.

Content will consist of less than 1 percent organics after wet screening, and less than 1/2 percent metallics by weight. The mixture will conform to the following description:

- Non-combustible and free flowing
- Less than 1% water solubles
- Moisture less than 10%

for clay (79). The finished experimental bricks met ASTM standards (ASTM C62-66 and C67-66) and required less fuel for the kiln than regular brick.

Possibilities for use of the fines in paving mixes are good according to members (88) of ASTM Committee D-4, Road and Paving Materials. However, market values will be low. There are many sources of minus 3/16-inch inorganic materials, for example, sand, mine tailings, process wastes (89). The only problems associated with using such abundant supplies of material in roadway construction have been water absorption and roundness of shape. Water retention in asphalt leads to swelling and cracking, often within a year of application. This would indicate that organic material contained in the fines would be undesirable because of potential to promote formation of small voids and retain water (90). This could be avoided; tabling of the fines likely would remove the organic materials if water elutriation and wet screening do not reduce them to an acceptable level.

The elutriating step can also be used to adjust the pH of inorganic fines over a range of approximately 6 to 9 by adding acids or bases to the water so as to achieve compatibility of the glass fines with paving mixes. The exact pH value, however, is not particularly important for most applications. For example, fines to be used in hot asphalt could vary from acidic to basic over a wide range without significantly affecting physical properties. The mechanical characteristics, i.e., angularity of piece shapes, are much more important for this use than chemical bonding (90).

Moisture in the fines should not present problems as long as the moisture content is relatively predictable. The material could be dried in a hot asphalt plant during manufacturing (86).

The only advantage of glass fines over commonly used rock aggregate would be that the angular shape of the glass fines should impart more strength (88) to pavement than would spherical sand, for example. A disadvantage may be that hydrated lime would be needed with the inorganic fines, perhaps in the range of 1 to 2 percent, to promote adhesion. This added expense is necessary because, without the lime, glass surface wetting will be insufficient to the detriment of paving physical properties (ASTM D242-70, D693-71a, D694-72, D1073, D1074-60, etc.)

A need exists throughout much of the United States for plus 3/16-inch size aggregate. Although inorganic fines likely could be sintered to produce plus 3/16-inch material, ASTM officials of Committee D-4 (88) were negative about prospects. Upgrading costs could not be covered by increased selling prices of the larger pieces sizes.

The recommended specification for inorganic fines was written loosely around the expected nature of the glass-rich by-product -- without requirement for further processing. Naturally, the specification can be tightened to fit individual user needs as markets develop and secondary processing becomes economically viable.

Refuse Derived Fuel

(Mixed Organics)

Background

Several of the dry separation systems which have been proposed for resource recovery (5) from municipal waste, and the generalized method for dry separation shown in Figure 1, utilizes an air classifier to separate the metals and glass (including stones and other heavy materials) from the light mixture of predominantly paper and film plastics. This latter category is mostly organic (carbon containing) and, therefore, suitable for use as a fuel. Similarly, wet processing systems can be used to prepare a dewatered, primarily organic fraction for use as a fuel; for example, the Black Clawson system (91) and a similar scheme proposed for Norwalk, Connecticut (92).

In April, 1972, the City of St. Louis, began shipping shredded, mixed municipal refuse (with the magnetic metals removed) to Union Electric Company to be used as a fuel in electric utility boilers (93) along with coal, as a demonstration program. After approximately six months of operation the experiment was proceeding well enough to encourage further burning of shredded refuse as a supplementary fuel but with the qualification that an air classification step be added so as to remove the non-combustibles (94) and this step was added a few months

thereafter. The non-combustibles in the fuel interfere with the materials handling, add to the residual ash, and decrease the fuel value per unit weight of fuel. These conclusions are illustrated by the fuel analyses of the material burned by the utility shown in Table 20 (95)(96). These values may be compared with similar analyses for common coal for power generation, shown in Table 21 (97). Coals are sold according to specification; the price paid for the coal is based on its quality, judged from analyses such as in Table 21 (98).

The composition of the light, organic portions of the refuse fuel, has been estimated for Norwalk, Connecticut, and is shown in Table 22 (92). The materials listed are either cellulosic or hydrocarbon in origin (except the leather) and, therefore, are expected to have a high heat value as a fuel. The potential heat value of such a mixture can be estimated from published figures of the heats of combustion of the various components; it is approximately 8000 BTU lb., on a dry weight basis. The ash content will depend principally on the particular mix of types of paper and the amount of garden waste.

The acceptability of air classified, shredded mixed municipal refuse as a fuel in utility boilers will depend on its composition, judged from analyses such as in Table 20 and as compared to analyses such as in Table 21. In other words, the processing of this fraction of refuse must be controlled to produce a fuel as close to commonly

Table 20

Average Fuel Composition - St. Louis

Dry Weight Basis

	Without Air Classification	Following Air Classification
Higher heating value, BTU/lb.	6293	7085
Sulfur, Wt.%	0.20	0.16
Chlorides, Wt.%	0.44	0.59
Ash, Wt.%	29.0	24.9
Moisture, as received, Wt.%	29.1	30.1

Source: References 94, 96

Table 21

Properties of Coal As A Fuel (97)

	Mid-Continental U.S. Bituminous	Wyoming Sub-Bituminous	Lignite
Heat Value (BTU/lb.)	11,500 - 13,000	8500 - 11,500	6500 - 8500
Sulfur (%)	3 - 5	--	--
Ash (%)	10 - 12	9 - 12	8 - 12

Note: All values given are on a dry weight basis.

Table 22

Norwalk Domestic Sampling
Composition Analysis

Components	Socio - Economic Income Level High Mean	Medium Mean	Low Mean
Fuel Source			
Paper Products	44.78%	41.25%	36.98%
Food & Garden Waste	16.69%	17.00%	20.93%
Plastics	4.01%	4.83%	3.96%
Rubber & Leather	.33%	.42%	.46%
Textiles	2.78%	5.82%	4.21%
Wood	.46%	1.03%	1.59%
Sub Total	69.05%	70.35%	68.13%

Source: Norwalk, Connecticut Recycling Plant, Grant Application to U. S. EPA, Volumes I-V, July 31, 1972.

used coals, as possible, if to be used with a minimum alteration to existing facilities and operating procedures. No doubt, the refuse-derived fuel will have an advantage over most coals in that it will be low in sulfur.

Recommended Specifications

A target specification for fuel derived from air classified, shredded mixed municipal refuse, termed here Refuse-Derived Fuel, or RDF, is shown in Table 23. Two physical forms are suggested. One is loose and free flowing to be blown into semi-or full suspension fired boilers, such as in St. Louis. The other form is briquetted, such as might be utilized in stoker fed boilers, which has been proposed for at least one city (99). It is presumed that the Refuse-Derived Fuel will almost always be fired along with another fuel, coal or oil, in the major proportion.

The stated moisture content of 30 percent in Table 21 is based on an estimate of the maximum moisture content of refuse likely to be encountered at a processing facility. Shredding and air classification are expected to reduce the moisture content compared to the moisture content of the "as received" refuse, although, this has not yet been quantified. The other values are chosen based on the analyses below.

Table 23

Target Specification for Refuse-Derived Fuel

Physical Form	For semi-suspension or full suspension burning, maximum particle size 4 inch. For full-suspension burning, maximum particle size 1-1/4 inch. For stoker fuel, briquetted, 1-1/2 to 2 inch maximum size.
Fuel Value	The higher heating value of each shipment shall be not less than 5000 BTU/lb., as received.
Analyses, dry weight basis	
Sulfur	0.3% max.
Total Chlorides	0.6% max.
Water Soluble Chlorides	0.3% max.
Ash	15% max.
Moisture	30% max.

Analyses

The maximum particle size of the fuel for different applications is stated on the basis of the St. Louis experience (93)(94), from the experience of a group planning to burn shredded industrial waste in a steam generating boiler (100), and published reports (99). The other values are chosen on the basis of analyses of the air classified light fraction of shredded, municipal refuse. There is reason to believe that minus four inch material may be acceptable if the air classification step produces a fuel consisting of just thin pieces of paper, film plastics, and the like.

Some few samples of air classified, shredded mixed municipal refuse (29) have been analyzed. The samples were prepared using the NCRR Mobile Air Classifier (a 10 ton per hour, zig zag unit) with feedstock from operating shredders. The fuel analyses were performed by Ralston Purina Company, the same laboratory that has been analyzing samples from St. Louis (93). Preliminary results are summarized in Table 24.

The fuel analyses for shredded, St. Louis refuse, air classified and not (Table 20) and for the air classifed material (Table 24) are not directly comparable. Refuse varies in composition with season of the year and part of the country.

Table 24

Properties of Refuse-Derived Fuel

Dry Weight Basis

FUEL	Fuel Value BTU/lb.	Composition Wt.% S	Cl	C	N	ASH
St. Louis MSW[a]	6,290	0.2	0.5	-	-	29.4
"Eco-fuel-I"[b]	6,900	0.1-0.2	0.1-0.2	39.6	0.9	11.5
RDF[c]	6,880	0.2	0.5	37.1	0.8	22.6
RDF, +3/16[d]	7,855	0.1	0.5	43.6	0.7	11.3
Paper[e]	7,500	0.1	-	45.4	0.3	6.0
Coal[e]	6,500 - 13,000	1-5	0.05	--	-	8-12

Notes: a. Shredded, but not air classified. Ref. 93.

b. Ref. 103

c. Air classified by NCRR. NCRR, unpublished.

d. Same as RDF, but the oversize from a 3/16 inch screen. NCRR, unpublished

e. Ref. 97.

Generally, air classification slightly increases the heat value and slightly decreases the ash content (101). The high ash content of some of the air classified samples is believed due to glass fines which were produced in the shredded and carried over with the light fraction (102). This view is supported by an analysis of the ash from samples from one city, shown in Table 25. Also shown in Table 25 are similar analyses for the ash from St. Louis refuse derived fuel delivered to Union Electric with air classification (96) and the composition of a typical flint container glass. The ash compositions, qualitatively, may be viewed as a mixture of glass, silica, clays, and minor constituents.

The ash content of the Refuse-Derived Fuel in the target specification (Table 23) is based on experimental results from several sources, summarized in Table 24. Note, however, these are preliminary results, except perhaps for the value for Eco-fuel-I (TM) from a commercial source (103). The low ash content claimed for this material, and the experimental result of 11 percent for one sample, encourages a value of 15 percent ash or lower in the target specification. Furthermore, a parametric study of the air classification step and of aerodynamic means to reduce inorganic fines (102), also support the idea of a specification of 15 percent ash.

Table 25

Composition of Ash from Refuse Derived Fuel[a]

	Ash, San Antonio[b] Wt.%	Ash, St. Louis[c] Wt.%	Flint Glass Wt.%
SiO_2	46.10	50.3	71.9
Al_2O_3	9.30	11.09	1.79
Fe_2O_3	7.01	7.76	0.036
TiO_2	1.11	0.84	0.015
CaO	17.63	12.15	11.04
MgO	1.40	1.28	0.66
Na_2O	6.01	8.37	12.97
K_2O	1.53	1.35	0.34
SO_3	7.55	1.45	0.20
P_2O_5	1.50	1.39	--

Notes:

[a]Less than 100 percent of the material is accounted for.

[b]Single Sample.

[c]Ref. 96

There has been concern that the chlorine content of refuse derived fuel is some ten times greater than coal and because of this, use of RDF will be detrimental to the operation of power generation boilers. It is important to point out that most of the chlorides in RDF may be water soluble (96). Furthermore, most of the available chlorine in solid waste is not attributable to any one category of materials in that waste (104). For example, approximately 36 percent of the chlorine can be accounted for as from plastics and 28 percent from paper. Some of this was shown to be water soluble (104), indicating inorganic chlorine, perhaps from table salt. If true, this material will be part of the ash when the fuel is burned and, unlike chlorine from organic compounds, not necessarily contribute to corrosion of metallic parts.

The term Refuse-Derived Fuel, or RDF, is used in the generic sense to indicate any solid fuel prepared by shredding and air classifying refuse. Air classifier light fraction may be further processed by chemical and/or mechanical means to upgrade its fuel properties. The end products would still be Refuse-Derived Fuels in the sense the term is used here. The term RDF was, to the best of our knowledge, coined by Collins (105).

SECTION VI

REFERENCES AND NOTES

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recovered from municipal solid waste, this would amount to 2.4 percent of U.S. production. It is unlikely that this small fraction would be enough to force large technological change at major steel producing mills. This is especially true in view of the fact that approximately 30 percent of domestic steel tonnage output is accounted for by scrap consumption now. (Derived from J. H. McGannon. The Making, Shaping and Treating of Steel. 9th ed. Pittsburgh, U.S. Steel Co., 1970. p. 254).

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SECTION VII

PUBLICATIONS

The National Center for Resource Recovery, Inc. has a major goal -- "research, analysis, and dissemination of information" -- regarding municipal solid waste. In keeping with its objectives, NCRR published a 367-page report in December, 1972 titled "Materials Recovery System, Engineering Feasibility Study" (7). Chapter five of the report, "Output Characteristics," contained preliminary specifications for recovered materials which were developed concurrently with research on this project.

Other publications based, in part, on work performed under the research grant reported here, are:

E. L. Michaels, K. L. Woodruff, W. L. Freyberger, H. Alter, "Heavy Media Separation of Aluminum from Municipal Solid Waste," paper presented at the AIME 103rd Meeting, February, 1974, Transactions AIME, in press.

H. Alter and K. L. Woodruff, "Particle Size Distributions of Shredded Refuse; Processing for Resource Recovery," Resource Recovery and Conservation, in press.

H. Alter, K. L. Woodruff, A. Fookson, B. Rogers, "Analysis of Newsprint Recovered from Mixed Municipal Solid Waste," Resource Recovery & Conservation, in press.

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SECTION VIII

APPENDIX

Representative Specifications Now Used In The Scrap Industry

Explanation of Terms Used

In ISIS* Specifications

a. Cleanness. All grades shall be free of dirt, nonferrous metals, or foreign material of any kind, and excessive rust and corrosion. However, the terms "free of dirt, nonferrous metals, or foreign material of any kind" are not intended to preclude the accidental inclusion of negligible amounts where it can be shown that this amount if unavoidable in the customary preparation and handling of the particular grade involved.

b. Off-grade material. The inclusion in a shipment of a particular grade of iron and steel scrap of a negligible amount of metallic material which exceeds to a minor extent the applicable size limitations, or which fails to a minor extent to meet the applicable requirements as to quality or kind of material, shall not change the classification of the shipment, provided it can be shown that the inclusion of such off-grade material is unavoidable in the customary preparation and handling of the grade involved.

c. Residual alloys. Wherever the term "free of alloys" is used in the classifications given herein, it shall mean that any alloys contained in the steel are residual and have not been added for the purpose of making an alloy steel. Steel scrap shall be considered free of alloys when the residual alloying elements do not exceed the following percentages:

	percent
Nickel	0.45
Chromium	0.20
Molybdenum	0.10
Manganese	1.65

The combined residuals other than manganese shall not exceed a total of 0.60 percent.

d. Deviations. Any deviations from the general classifications of iron and steel scrap may be consummated by mutual agreement between buyer and seller.

*Source: Institute of Scrap Iron & Steel, Inc.
1729 H Street, N.W.
Washington, D.C. 20006

Accepted Specifications For Selected Remelting Grades of Steel Scrap

BASIC OPEN HEARTH, BASIC OXYGEN, ELECTRIC FURNACE, AND BLAST FURNACE GRADES	ISIS CODE NO.
Shredded Tin Cans For Remelting Shredded Steel cans, tin coated or tin free, may include aluminum tops but must be free of aluminum cans, nonferrous metals except those used in can construction, and non-metallics of any kind.	213
Bundled No. 1 Steel. Wrought iron and/or steel scrap 1/8 inch or over in thickness, compressed to charging box size and weighing not less than 74 pounds per cubic foot. Free of all metal coated material.	217
Bundled No. 2 Steel. Wrought iron or steel scrap, black or galvanized, 1/8 inch and over in thickness, compressed to charging box size and weighing not less than 75 pounds per cubic foot. Auto body and fender stock, burnt or hand stripped, may constitute a maximum of 60 percent by weight. (This percent based on makeup of auto body, chassis, driveshafts, and bumpers.) Free of all coated material, except as found on automobiles.	218

Source: Institute of Scrap Iron & Steel, Inc.
1729 H Street, N.W.
Washington, D.C. 20006

UNITED STATES STEEL CORPORATION

OPEN HEARTH CARBON STEEL SCRAP SPECIFICATIONS

All grades must be free of alloy and stainless scrap, non-ferrous metals, closed containers, or foreign material of any kind and free of excessive dirt, rust, corrosion, paint, grease and oil.

1. No. 1 Bundles. New black carbon steel sheet scrap, clippings, or skeleton scrap, hydraulically compressed or hand bundled to charging box size and weighing not less than 75 pounds per cubic foot. (Hand bundles must also be tightly secured and stand handling with a magnet). Must be free of paint or protective coating of any kind. May include mandrel wound bundles or skeleton reels, tightly secured. Must not include turnings, beadwire, electrical sheets or any material over 0.5% of silicon.

2. No. 1 Heavy Melting Steel. Clean wrought iron or carbon steel scrap 1/4 inch and over in thickness, not over 18 inches in width and not over 5 feet in length. Individual pieces must be free from attachments, and so cut as to lie flat in the charging box. May include new mashed pipe ends, 4 inches and over. Must not include cast iron, malleable iron, boiler tubes, fire boxes, burnt boiler plate, annealing boxes, welding rods, pit scrap, slag, skulls, spills, runouts or similar material.

3. No. 1 Busheling. Clean new carbon steel scrap 1/16 inch and over in thickness, not exceeding 12 inches in any dimension, including new factory busheling 20 gauge or heavier (for example, sheet clippings, stampings, etc.). May not contain burnt material or auto body and fender stock. Must be free of metal coated, limed or porcelain enameled stock.

4. No. 2 Heavy Melting Steel. Wrought iron or carbon steel scrap, black or galvanized, 1/8 inch and over in thickness, not over 18 inches in width and not over 3 feet in length. Individual pieces must be

free from attachments and so cut as to lie flat in charging box. May include pipe 4 inches and under in diameter, cut 3 feet or less. Must not include automobile body and fender stock, cast iron, malleable iron, boiler tubes, fire boxes, burnt boiler plate, annealing boxes, welding rods, pit scrap, slag, skulls, runouts or similar material.

5. No. 2 Bundles. Body and fender carbon steel scrap, or old black and/or galvanized carbon steel scrap, hydraulically compressed to charging box size and weighing not less than 75 pounds per cubic foot. Must not include turnings, beadwire, vitreous enameled stock, tin cans, tin plate, terne plate or other metal coated material. Painted or lacquered material shall not be considered as metal coated material. Must be free of rubber, wood and copper, including BX cable stripped and unstripped. May include hydraulically compressed black or galvanized fence wire and light coil springs.

6. No. 3 Bundles. Off-grade material, compressed to charging box size and weighing not less than 75 pounds per cubic foot. May include completely stripped BX cable. May include galvanized, vitreous enameled and other coated ferrous scrap not suitable for inclusion in No. 2 Bundles, except tin and terne coated material which are not acceptable. Must be free of dirt, rubber, wood, non-ferrous metals, tin cans, and non-metallics of any kind.

7. Incinerator Bundles. Tin can scrap, compressed to charging box size and weighing not less than 75 pounds per cubic foot. Must have been processed through a recognized garbage incinerator, must be free of dirt, non-ferrous metals and non-metallics of any kind.

United States Steel Corporation
Purchasing Division

August 18, 1970

UNITED STATES STEEL CORPORATION

ELECTRIC FURNACE SCRAP SPECIFICATIONS

All scrap must not contain over 0.05% phosphorous or sulphur, and not over 0.5% silicon and free of all alloys.

1. Billet Bloom and Forge Crops. Must be new material not less than 2 inches in thickness and not over 18 inches in width and 36 inches in length.

2. Bar Crops and Plate Scrap. Must be new material not less than 1/4 inch in thickness and not over 18 inches in width and 36 inches in length.

3. Cut Structural and Plate Scrap. Clean, new, open hearth steel plates and structural shapes, crop ends, shearings, must not be less than 1/4 inch in thickness nor over 18 inches in width and 36 inches in length.

4. Flashings. Clean, new, cut flashings at least 1/4 inch in thickness in body of flashing and cut not to exceed 12 inches in width and 24 inches in length. Uncut flashings not acceptable.

United States Steel Corporation
Purchasing Division

August 18, 1970

Accepted Specifications

For Selected Grades

Of Scrap Aluminum

Code	Item Description
Take 75	NEW ALUMINUM CAN STOCK Shall consist of new low copper aluminum can stock and clippings, clean, lithographed or not lithographed, and coated with clear lacquer but free of lids with sealers, iron, dirt and other foreign contamination. Oil not to exceed 1%.
Talc 75	OLD CAN STOCK Shall consist of clean old aluminum cans decorated or clear, free of iron, dirt, liquid and/or other foreign contamination.
Tall 80	E. C. ALUMINUM NODULES Shall consist of clean E. C. aluminum, chopped or shredded, free of screening, hair-wire, iron, insulation, copper and other foreign contamination. Must be free of minus 20 mesh material. Must contain 99.45% aluminum content.
Tense 86	MIXED ALUMINUM CASTINGS Shall consist of clean, new, pure, uncoated, unalloyed aluminum foil, free from anodized foil, radar foil and chaff, paper plastics, or any other foreign materials. Hydraulically briquetted material by arrangement only.
Testy 89	OLD ALUMINUM FOIL Shall consist of clean, old, pure, uncoated, unalloyed aluminum foil, free from anodized foil, radar foil and chaff, paper, plastics, or any other foreign materials. Hydraulically briquetted material by arrangement only.

Thigh 90	ALUMINUM GRINDINGS Should be sold on recovery basis or by special arrangements with purchaser.
Throb 92	SWEATED ALUMINUM Shall consist of aluminum scrap which has been sweated or melted into a form or shape such as an ingot, pig or slab for convenience in shipping; to be free from corrosion, drosses or any foreign materials. Should be sold subject to sample analysis..
Tooth 93	SEGREGATED NEW ALUMINUM ALLOY CLIPPINGS AND SOLIDS Shall consist of new, clean, uncoated and unpainted aluminum scrap of one specified aluminum alloy only and to be free of foil, hair wire, wire screen, dirt. and other foreign substances. Oil and grease not to total more than 1%. Also free from punchings less than 1/2% in size. New cab stock subject to arrangement between buyer and seller.
Tough 94	MIXED NEW ALUMINUM ALLOY CLIPPINGS AND SOLIDS Shall consist of new, clean, uncoated and unpainted aluminum scrap of two or more alloys free of 70S series and to be free of foil, hair wire, wire screen, dirt and other foreign substances. Oil and grease not to total more than 1%. Also free from punchings less than 1/2" in size. New Can Stock subject to arrangement between buyer and seller.

Source: Standard Classification for Nonferrous Scrap Metals, Circular NF-73, National Association of Recycling Industries, 330 Madison Ave., New York, New York 10017.